AN INVENTORY OF THE SPIDERS IN TWO PRIMARY TROPICAL FORESTS IN SABAH, NORTH BORNEO

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Collecting trips were made to a primary rainforest area at 1500-1900m altitude (Mt Kinabalu National Park) and a primary lowland rainforest (Danum Valley Field Centre) in Sabah, North Borneo. For comparison, a strongly degraded secondary forest in the town Kota Kinabalu was also sampled. All the material, with the exception of the mygalomorphs and salticids, has been identified and compared with collections from Sarawak, Kalimantan and Sumatra. 254 species were distinguished in approximately 120 genera, 35 could be identified as known species, seven of which were clearly synanthropic, the rest are undescribed. 207 species were found in one locality only: 85% of the species from Kinabalu, 70% of the species of Danum and 50% of the species from the town park. Widespread species were found mainly in the Araneidae, Pholcidae, Oonopidae, Clubionidae and Salticidae. A list of the genera and species is given. □*Biodiversity, rainforest, Asia, Araneae.*

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Tropical rainforests, covering only 6% of the Earth's surface, are believed to harbour more than half of all terrestrial animal species, of which less than 10% are described at present (Stork and Gaston, 1990). Inventorying the spider fauna of rainforests in south-east Asia has given spider taxonomy a new turn, especially so after the introduction of a new sampling method that targets canopy arthropods.

Most rainforests in Asia have now been destroyed or degraded, but the number of undescribed species is still overwhelming. The rapid destruction of our rainforests is an incentive to securing as much data as possible as ... 'an extensive program of inventorying aimed at estimating diversity of species ... is essential for a fuller understanding of the role of biodiversity in ecosystem function' (Coddington *et al.*, 1992).

Records of spiders from Borneo are extremely poor. With more than 30,000 species of spiders described so far, only about 160 named spider species have been described or recorded for the whole of Borneo; 65 of these are salticids. Only 96 spider species were reported from Borneo before World War I. Wanless and Hillyard (1984) present a list of species collected during the arachnological survey of Gunung Mulu National Park, Sarawak; 360 species were collected in all families, 38 of which were identified with known species, another 14 with reserve; 20 identified species are salticids. From Sabah, a mere 20 spider species are known, all published since 1979 (Deeleman-Reinhold, 1980, 1987; Lehtinen, 1979, 1981, 1982; Levi, 1982, 1983; Okuma, 1988; Platnick and Murphy, 1984; Wanless, 1987).

In a privately undertaken program of inventorying spiders of primary and secondary forests in south-east Asia, during the last 14 years I have been engaged, with the help of other, partly autochthonous collectors, in surveying the spider fauna of south-east Asia, mainly Indonesia, Malaysia, Thailand, Sri Lanka and the Philippines. As part of this initiative, I made three collecting trips to Sabah in the north-eastern part of Borneo.

METHODS

In June 1979, July 1980 and April-May 1991, I collected spiders in the primary rainforest of Mount Kinabalu National Park at altitudes of 1500-1900m. In May 1991, 2 days were spent collecting at an altitude of 500m (Poring Hot Springs). In May 1991, spiders were collected in lowland primary forest around the Danum Valley Field Centre in eastern Sabah. For comparison, some time was also spent collecting in the town park in Kota Kinabalu.

The spiders were collected by hand picking, sweeping, litter sieving and pitfall trapping on the ground. All araneomorph spiders, with the exception of the Salticidae have been identified (Tables 1-3). The collected spiders were compared with most specimens of the above mentioned south-east Asia collection. Identification was done as

Oonopidae
Dysderina sp. (1)
Gamasomorpha sp. (2), Sabah
sp. (2)
Ischnothyreus sp. (4)
Opopaea ? (1)
Orchestina sp. (1)
sp. (1), Sabah, only below 600m
Plectopilus sp. (1)
Xyphinus lemniscatus Deeleman
sp. (1), *
Undescribed genus (1), also lower in secondary forest
Tetrablemmidae
Ablemma
Borneomma
Sabahya
circumspectans Deeleman, also lower in secondary forest
roberti Deeleman
kinabaluana Deeleman
bispinosa Deeleman
sp. (1)*
Ochyroceratidae
Psiloderces sp. (1)
Speocera sp. (1)
Undescribed genus (1)
Scytodidae
Scytodes pallida Doleschall, widespread*
Pholcidae
Uthina sp. (1), Sabah
sp. (1)*
Spermophora sp. (1), Sabah
muser Bristowe, widespread*
Belisana sp. (1)
Undescribed genus (1)
Heteropodidae
Heteropoda sp. (1)
sp. (1)canopy walk*
Thelcticopis sp. (1)
Olios sp. (1)*
Undescribed genus (1), in grass
Undescribed genus (1), canopy walk*
Ctenidae
Ctenus sp. (1)
Clubionidae s.l.
Clubioninae
Cheiracanthium sp. (1)
Clubiona sp. (4)
sp. (1) canopy walk*
sp. (1)widespread
Phrurolithinae
Otacilia sp. (1), also at 500m
Sesieutes sp. (1), Sabah
sp. (1)
Teutamus sp. (1)
Orthobula sp. (1), Sabah
Corinninae
New genus (1)
Gnaphosidae
Jacaena sp. (1), on the lawn
Palpimanidae
Bougrius sp. (1)
Zodariidae
Asceua sp. (1)
sp. (1)*
Malinella sp. (3)
Undescribed genus? (2)
Thomisidae
Borboropactus sp. (1)
Lycopus sp. (1), also at 500m
Misumenops sp. (1), canopy walk*
Pagida sp. (1)
Phrynarachne sp. (1)
Oxyopidae
Oxyopes sp. (1), canopy walk*
Pisauridae
Polybaea sp. (1)
Lycosidae
Pardosa sp. (1)
Undescribed genus (1)
Hippasinae (1)
Hahniidae
Alistra sp. (1)
Hahnia (2)
Hersiliidae
Hersilia sp. (1)
Theridiidae
Achaearanea mundula (L. Koch), widespread
tepidariorum (C.L. Koch), worldwide
sp. (1)
spp. (3)*
Anelosimus sp. (1), canopy walk*
Argyrodes xiphias Thorell, widespread
Rhomphaea sp. (1)
Chrysso sp. (1)
Coleosoma sp. (2), Sabah
Cascinda sp. (1)
sp. (1)*
Dipoena sp. (5)
sp. (1)*
Episinus sp. (2)
Janula sp. (1), Sabah
Meotipa sp. (1)*
Phoroncidia sp. (2), Sabah
sp. (1)*
Theridion sp. (4)
spp. (3)*, 1 on canopy walk
Undescribed genus (2)
sp. (1), also at 500m
Undescribed genus (1)
Mimetidae
Mimetus sp. (3)
Theridiosomatidae
Plato sp. (1)
Theridiosoma sp. (1)
Mysmenidae
Undescribed genus (1)
Tetragnathidae
Leucauge celebesiana Walckenaer, widespread
spp. (2), Sabah
Glenognatha sp. (1)
Mesida sp. (4)
Undescribed genus I (2)
Undescribed genus II (2), also at 500m
Undescribed genus III, (1), also at 500m
Araneidae
Araneus sp. (1)
Argiope reinwardtii Doleschall, widespread
aemula (Walckenaer), widespread
Cyclosa bifida Doleschall, widespread
Cyrtophora sp. (1)
? Eriophora sp. (1)
Gasteracantha sp. (1)*
Milonia brevipes Thorell, widespread
Neoscona nautica L. Koch, world tropics
Undescribed genus (1)
Linyphiidae
Neriene beccari Thorell, widespread
Kuala sp. (1)
Parameioneta sp. (1)
Nasoona sp. (3)
sp. (1)*
Undescribed genus II (1)
Undescribed genus III (1)
Undescribed genus IV (1)
Undescribed genus V (2)
Uloboridae
Philoponella sp. (1)
Uloborus lugubris Thorell, widespread*
Psechridae
Psechrus kinabalu Levi

Table 1. Spiders from Mount Kinabalu, 1500-1900m (Headquarters and Power Station) and 500m (Poring Hot Springs), primary rainforest, 18 collecting days in April-May, June and July. Family order is 'phylogenetic'. List gives no. of undescribed species in parentheses and notes on species.*= only at 500m.

much as possible with the aid of modern revisions but, where these do not exist, I had to rely on the keys in Simon (1892-1903) and the Latin descriptions (without illustrations) of Thorell (1877-1899) and Simon. Many nineteenth century types deposited in Genova, Paris and London were studied. Only species of which adults were collected are considered here.

RESULTS

From the three main prospected localities in Sabah, a total of 254 species from most spiders families (for practical reasons the mygalomorphs and the salticids were excluded) could be distinguished. Of these, 35 species could be identified as described species, seven of which are clearly synanthropic.

On Mt Kinabalu (1500-1900m), 135 species were collected in 18 days (41 species represented by one specimen only); 25 species were collected in two collecting days at Poring Hot Springs, lower down on the mountain slope at 500-600m; four of these were shared with the 1500-1900m site (see Table 1). For six of the 19 described and named species this is the type locality (Deeleman-Reinhold, 1980, 1987; Levi, 1982). 132 species (85%) were collected only in Kinabalu; 24 species were also found elsewhere.

Oonopidae
Dysderina sp. (1)
Gamasomorpha sp. (2), Sabah
Ischnothyreus peltifer (Simon), world tropics sp. (5)
Opopaea ? sp. (1), Sabah
Orchestina sp. (1)
Plectopilus sp. (1), Sabah
Xyphinus sp. (1)
Tetrablemmidae
Ablemma sp. (1)
Ochyroceratidae
Meringocera sp. (1)
Speocera sp. (1)
Pholcidae
Calapnita phasmoides Deeleman, Borneo
Smeringopus pallidus (Blackwall), world tropics
Pholcus sp. (2) (1) in logged area
Spermophora sp. (1), Sabah
Belisana sp. (1)
Heteropodidae
Heteropoda sp. (1)
sp. (1), in logged area
Olios sp. (1)
Ctenidae
Ctenus sp. (1)
Gnaphosidae
Micythus sp. (1)widespread
Clubionidae s.l.
Clubioninae
Cheiracanthium sp. (1)
Clubiona sp. (3)
Castianeirinae
Artius sp. (1)
Phrurolithinae
Sesieutes sp. (1), Sabah
Corinninae
Undescribed genus (1)
Palpimanidae
Boagrius sp. (1)
Zodariidae
Malinella sp. (2)
Thomisiidae
Borbomopactus sp. (1)
Losobates sp. (1), in logged area
Pagida sp. (1), in logged area
Peritraeus sp. (1)
Synema sp. (1)
Talaus sp. (1), in logged area
Tmarus sp. (2), in logged area
Pisauridae
Polybaea sp. (1)
Oxyopidae
Oxyopes lineatipes C.L. Koch, widespread sp. (1)
Tapponia superba Thorell, widespread
Lycosidae
Hippasa
Wadicosa birmanica (Thorell), widespread, in logged area;
Pardosa putiola (Thorell), widespread
Hahniidae
Alistra sp. (1)
Hersiliidae
Hersilia sp. (1)
Theridiidae
Achaearanea sp. (1)
Argyrodes sp. (1)
Cephalobares sp. (1)
Chrysso sp. (1)
Coleosoma sp. (1), Sabah
Coscinida sp. (1)
Dipoena sp. (2)
Episinus sp. (1)
Janula sp. (1), Sabah
Theridion sp. (4)
Undescribed genus (1)
Mimetidae
Mimetus sp. (1)
Mysmenidae
Undescribed genus (1)
Anapidae
Pseudanapis paroculus Simon, widespread
Leucauge sp. (1), Sabah
sp. (1)
Glenognatha sp. (1)
Araneidae
Cuerostris sp. (1)
Cyclosa bifida Doleschall, widespread
mulmeinensis (Thorell), widespread
Gasteracantha sp. (1)
Gea subarmata Thorell, widespread
Larinia phthisica L. Koch, widespread
Milonia trifasciata Thorell, widespread
Neoscona nautica L. Koch, world tropics sp. (1)
Poltys sp. (1)
Undescribed genus I (1)
Undescribed genus II (1)
Linyphiidae
Undescribed genus (1)
Uloboridae
Philoponella sp. (2)

Table 2. Spiders from Danum Valley Field Centre, primary lowland forest, 8 collecting days in May; some species, mostly Thomisidae, in freshly logged area. Family order is 'phylogenetic'. List gives no. of undescribed species in parentheses and notes on species.

Compared to the lowland catches, a predominance of Linyphiidae was found.

In primary lowland forests around Danum Valley Field Centre in East Sabah, 90 species were collected in 9 days (Table 2); 14 species have been previously described. Of these, 67 species (70%) were only found at Danum, and 23 were also found elsewhere. In a freshly logged area, thomisids were particularly diversified.

In the secondary forest of Signal Hill in the township of Kota Kinabalu, 16 species were collected, 7 of which could be identified to species. Eight species were found also elsewhere, and 8 species (50%) were collected only on that site.

DISCUSSION

The main conclusion is that in tropical forests, spider species known from only one locality are enormously preponderant even though all distribution types from cosmotropical to very restricted ranges were encountered.

In a total of 254 species from the three localities (Tables 1-3), 207 were collected at one locality only, 92 of which were 'singletons'. Is this due to the lack of data only, or is a high percentage of endemic species real? This phenomenon occurs much more frequently in some families than in others. Quite often, in adjacent localities a sister species is found. In a long-term inventory of a 1-2 km^2 area on the northern side of the Sibolangit range, on Gunung Leuser in Sumatra (Deeleman-Reinhold, unpublished data), spiders were collected once a week for two years. A similar study was conducted on the other side of the ridge. Less than half of the species were found on both sides of the range! Therefore, endemism in spiders seems characteristic of primary rainforests, even though the real extent of distribution ranges will only be revealed after long and extensive sampling. For example, recent studies on south-east Asian Linyphiidae (Millidge and Russell-Smith, 1992) report 27 species, 26 of which new, described in 11 new and four known genera, all new species were recorded from only one locality (see also Scharff, 1992).

Also, widely distributed species were often found in human-made habitats. In such habitats most species described in the last century were found. In the course of identifying large south-

Oonopidae	*Psilochorus* sp. (1)widespread	sp. (1)
Ischnothyreus peltifer (Simon), world tropics	**Ctenidae**	**Tetragnathidae**
sp. (1)	*Ctenus* sp. (1)	*Leucauge* sp. (1)
Plectoptilus sp. (1)	**Clubionidae** s.l.	**Araneidae**
Ochyroceratidae	*Oedignatha scrobiculata* Simon, widespread	*Neoscona punctigera* Doleschall, widespread
Psiloderces sp. (1)	**Palpimanidae**	**Uloboridae**
Theotima minutissima (Petrunkevitch), world tropics	*Boagrius* sp. (1)	*Uloborus humeralis* Hasselt, widespread
Pholcidae	**Theridiidae**	
Uthina luzonica Simon, widespread	*Janula* sp. (1)	
	Theridion tenuissima Thorell, widespread	

Table 3. Spiders from town-park Signal Hill, Kota Kinabalu (2 collecting days). Family order is 'phylogenetic'. List gives no. of undescribed species in parentheses and notes on species.

east Asian collections it appeared that the majority of the species described prior to the early 20th century occur in habitats created by humans rather than in the rainforests. Thus, the spider fauna of the latter is still almost unknown.

A high degree of endemism seems to occur in certain families; other families which include a relatively high number of widely distributed species are Araneidae, Gnaphosidae, Oonopidae, Pholcidae and Salticidae. Occasionally, one or two species in a family are able to disperse considerably, whereas their relatives have remained limited to a restricted area. Among the best dispersers are some of the smallest known litter-dwelling spiders, with a body length of less than 1mm, which independently seem to have developed methods to overcome the vicissitudes of ballooning, e.g. the tiny armoured anapid *Pseudanapis paroculus* Simon is distributed over much of tropical south-east Asia both in primary and secondary forests. The small ochyroceratid *Theotima minutissima* (Petrunkevitch) and the oonopid spider *Ischnothyreus peltifer* (Simon) are distributed over the palaeo- and neotropics, where they live side by side with local congeners. Also larger spiders have been found to be widely distributed in humid forest, such as some *Cyclosa*, *Argiope*, *Acusilas*, *Neoscona* and *Gasteracantha* species, but also the delicate, almost transparent pholcid *Calapnita vermiformis* Simon.

The number of small-range species in both primary and secondary evergreen forests seems to be enormously higher than we are used to in temperate climates. Very few wide-spread species seem to occur naturally on Mount Kinabalu; more were found in lowland forest.

It is premature to estimate the total number of species present. Richest in species probably is the family Salticidae. Also numerous in species are the Theridiidae, Oonopidae, Araneidae, Clubionidae s.l. and Tetragnathidae in that order (see also Wanless and Hillyard, 1984 for Gunung Mulu).

Some genera have been particularly speciose in primary forest. In *Ischnothyreus* I found 11 species in Sabah (10 undescribed); in *Theridion* 11; in *Dipoena* 8; and in *Clubiona* 8 (all undescribed).

One final remark on diversity. Among the strongly represented families, diversity in the following families appears to be higher than average: Pholcidae, Clubionidae *s. lat.*, Tetragnathidae, Araneidae, Linyphiidae.

This study indicates that, when replacing primary forest by secondary plantations, the loss of species diversity of spiders is enormous.

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